Chapter 6
Exposing Inequities Within Teacher Professional Development and Its Impact on Advancing Equity, Diversity and Social Justice in STEM Education

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6.1 Introduction

The call to develop a more scientifically literate society in the United States has been prominent for decades. Scientific literate individuals are those who draw on the knowledge and practices of science, such as using epistemologically sound reasoning to ask questions or seek evidence-based explanations to gain an understanding of current or new knowledge regarding natural phenomena (Next Generation Science Standards, Lead States, 2013). In this effort, scientific literate individuals use their critical thinking abilities to engage in personal decision making that affects their personal wellbeing, that of others when engaging in science-based social issues, and that of the planet by supporting eco-friendly practices and behaviors (National Academies of Sciences [NAS], 2016; Yacoubian, 2018).

Scientific literacy in the United States has also increased economic productivity through the development and utilization of knowledge and products that better our existence (National Academies of Sciences, Engineering, and Medicine, 2016). As such, industry benefits from individuals who can draw on science and different disciplinary literacies such as mathematics, technology and engineering or STEM literacies. In fact, the need for STEM professionals has risen in the past decades to address more complex societal and technological issues, such as effectively addressing climate change and healthcare concerns (Knipprath et al., 2018). However, the US is not developing enough STEM professionals from diverse cultural

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backgrounds (Kennedy et al., 2021). A lack of culturally diverse STEM professionals limits the kinds of perspectives and approaches needed to solve everyday problems (NGSS, 2013). This effect is due in part to a lack of targeted educational efforts to adequately prepare teachers to teach the next generation of STEM literate students. Teachers are often hindered by a STEM knowledge gap (Aguirre-Muñoz et al., 2021; Madani, 2020). Thus, STEM teachers' professional knowledge needs to be reexamined to address teachers' needs for enacting effective STEM instruction.

Efforts to support STEM education have been placed at the forefront of many educational and funding initiatives; however, many hurdles have prevented the implementation of effective STEM education and teacher training (Margot & Kettler, 2019), particularly with educators teaching traditionally marginalized students from low socio-economic status (low-SES) and culturally and linguistically diverse (CLD) backgrounds. At the root of these hurdles are educational inequities evident in the disproportionate availability of intellectual and instructional resources offered to these students (Banilower et al., 2018). In this chapter, the authors first present our theoretical underpinnings of critical cross-cultural education. This is followed by a discussion on various structural inequalities that prevent equal access to available resources. We then discuss the current state of STEM PD in the state of Georgia to highlight the lack of funding and accountability measures for the implementation of the approaches introduced regarding STEM education and social justice agendas. We also present examples of our successes with teaching STEM despite receiving little to no funding. We highlight the STEMITL project, a small-funded project, as an example for integrating STEM curricula and share study findings to showcase the importance for modeling STEM curricula with preservice teachers. We also discuss examples of math method course assignments for integrating STEM. Lastly, we share our challenges seeking grant funding targeting STEM-based PD for local, rural teachers. We conclude with recommendations for grant funders of STEM-based professional development targeting equitable and socially just practices.

6.2 Inequities in STEM Education

6.2.1 Theoretical Underpinnings

Historically, pervasive structural inequalities are often felt by students from low-SES and CLD backgrounds attending public schools in the United States (Urrieta & Villenas, 2013; Valencia, 2010). According to Valencia (2010), structural inequalities exist when powerful groups and individuals, such as legislators and school board members, fail to optimize and provide equal educational opportunities for CLD and low-SES students. While many paradigms exist that examine power relations and their effects on institutionalized inequities for CLD and low-SES students, we draw on critical cross-cultural education as a theoretical framework for exploring how social change can be brought on by teaching about power dynamics between different cultural groups (Rodriguez & Morrison, 2019). For social change to occur, educational policies and practices must support diversity, equity and social justice. Rodriguez and Morrison (2019) define diversity as "the recognition of physical and social characteristics that make individuals unique and celebrating this uniqueness as a source of strength for the community at large. They also define equity as "the enactment of specific policies and practices to ensure equitable access and opportunities for success for everyone" (p. 28). Equitable access in science education, according to the National Research Council (NRC, 2012) means that students are provided with quality teachers and instruction, time, space and material resources to learn and engage in science and engineering practices. Lastly, Rodriguez and Morrison (2019) define social justice as the conceptual framework guiding the enactment or specific policies and practices to promote diversity and equity.

Social justice education is aligned with critical theory and focuses on examining diversity and equity issues, with the aims to dismantle the powers sustaining structural inequalities and to empower teachers and students to enact change (Freire, 1998; Giroux, 1983). This change can be exercised in various forms, for example when engaging in knowledge construction or engaging in activism (Ladson-Billings, 1992, 2014). Professional Development on social justice education is another form of social justice engagement that can help develop teachers' understanding of structural inequalities and anti-racist, anti-classist, anti-deficit views (Dover et al., 2020; Morales-Doyle, 2016). Also, teachers can be assisted with transforming curricula that provide students opportunities to examine how power affects the kinds of knowledge that are valued and those that are ignored (Dover et al., 2020). Moreover, with PD that focuses on utilizing students' Funds of Knowledge (González et al., 2005), science teachers can enrich curricula from diverse perspectives so that students: (a) feel included and validated when their inherited cultural knowledge is part of the curricula they learn; (b) apply their understanding of science to explain the natural world; (c) use this knowledge to engage in civic and personal duties that impact their well-being; and (d) enact change to disrupt oppressive practices and behaviors (Banks & McGee Banks, 1993; Ladson-Billings, 1992; Suriel & Freeman, in press). Funds of Knowledge refers to the cultural knowledge that individuals possess and that has been inherited or experienced and utilized to make sense of the world (González et al., 2005). Though much more is known now about what is needed to change existing structural inequities in education, socially unjust practices relating to high quality STEM instruction for the low-SES and CLD students persist (National Academies of Sciences, Engineering, and Medicine, 2016). In the next section, we present four sources of evidence that illustrate how social inequities are manifested through structural inequities.

6.2.1.1 Student Performance on STEM-Based Standardized Exams

One source of evidence of structural inequalities is the resulting student performance on STEM-based standardized exams. National measures of student learning outcomes based on standardized tests consistently show that on average, students from low-SES and CLD backgrounds underperform academically compared to their wealthier and White peers (Hanushek et al., 2020). For example, the National Assessment of Educational Progress (NAEP) report that CLD and low-SES students, on average and across the grades, scored around 30 points lower compared to their counterparts on the NAEP science, technology, engineering and mathematics assessments (National Science Board [NSB], 2018). Consequently, academic underperformance among low-SES and CLD students affects their prospects for enrolling in advanced STEM courses in high school, entering postsecondary education and earning college degrees, particularly in lucrative STEM fields (Mau & Li, 2018). Investments in STEM education are expected to grow; low-SES and CLD students are at a disadvantage if they are unprepared to meet this growing demand for STEM professionals (National Science Board [NSB], 2020).

6.2.1.2 Inadequate Learning Resources

A second source of evidence for structural inequalities for the low-SES and CLD students is decreased funding for education preventing access to learning resources. In the state of Georgia, for example, funding for education has been substantially cut 10.2 billion dollars in the last two decades (Lee and Georgia Policy Institute, 2020). Cuts on educational funding affect the quantity and quality of learning resources, which are much needed to learn STEM. The effects of limited funding for learning are even more prominent in light of the COVID-19 pandemic school closures. Studies on school-related pandemic restrictions revealed that children in low-SES areas did not have adequate resources to continue learning (Clark, 2018). In fact, an increased learning loss has resulted for low-SES and CLD students who lacked school-provided personal digital devices and internet connectivity to continue learning from home (Kaffenberger, 2021).

6.2.1.3 STEM vs. Non-STEM Programs

A third source of evidence of structural inequalities for low-SES and CLD students can be noted in the limited access to STEM-based enrichment programs, which restricts the participation of students who may need it the most. For example, in the state of Georgia, the student population in public schools are majority CLD students and low SES (Georgia Department of Education [GADOE], 2021). While there is a noted 1000% increase in the number of STEM certified schools in the last decade in the state of Georgia, approximately 3% of public schools are STEM/STEAM certified (STEM/STEAM Georgia, n.d.). The lack of access to STEM schools, particularly for Georgia's CLD students limits their opportunities to quality STEM curricula.

Moreover, STEM-based programs often require that students demonstrate high cognitive aptitude in program entrance exams. These exams, or evidence of participation on highly rigorous courses may be unattainable and may serve as barriers for low-SES students and English language learners who may not have access to the same resources and social capital as their wealthier and White peers (Coleman, 2020). Structural inequalities have prevented the access to enriching resources that can make these students competitive for these opportunities. Lastly, compounding this issue is the abstruseness of targeted funding for non-STEM-focused programs. STEM-based programs are often funded and additionally supplemented by public and private grants; however, it is not clear how much funding is provided to develop STEM literacy in teachers and students who do not participate in STEM-focused programs.

6.2.1.4 Unprepared Teachers

Lastly, a fourth source of evidence of structural inequalities often experienced by CLD and low-SES children is instruction that does not address integrated STEM nor reflect students' funds of knowledge, which may serve to disengage them from learning. It is well documented that teachers are not adequately prepared to teach STEM (Madani, 2020) or social justice education (Fabionar, 2020). While social justice education has been professed, teacher training on social justice education is still not prominent in teacher education programs. Teaching for social justice in Teacher Preparatory Programs has been a challenge for various reasons.

A challenge that many Teacher Preparatory Programs (TTP) face is that institutions of higher education may not prioritize social justice education, particularly in the current political climate where teaching for social justice has been an unduly incendiary political topic for some. Also, TTP may offer only a single course addressing student diversity, but many of these courses are non-specific to effective disciplinary instruction and may not emphasize the eradication of educational inequities experienced by low-SES and CLD learners. For example, these courses may not emphasize how teachers can: a) draw on students' cultural assets to teach and engage learners with STEM; b) engage students in examining STEM curricula for diverse perspectives, particularly from CLD scholars, and in doing so, rewriting more balanced narratives representing diverse funds of science knowledge (Razfar & Nasir, 2019); and c) create and support equitable STEM learning environments. Teacher educators are also partly to blame for this lack of teacher preparation in that they themselves may not possess the knowledge to teach for social justice within science education (Underwood & Mensah, 2018). In sum, a lack of focused teacher preparation targeting CLD and low-SES students is due in part to interest convergence, policy making that supports hegemonic supremacy (Dixson & Anderson, 2018; Urrieta Jr., 2009) and deficit thinking about what teachers can or cannot learn (Valencia, 2010). Thus, STEM teachers are unprepared to effectively teach CLD and low-SES children in ways that draw on their cultural and inherited assets (Banilower et al., 2018; Suriel & Atwater, 2012).

6.2.2 Development and Use of Intellectual and Material Resources for STEM Education

To address these disparities, a few initiatives have been implemented, to varying degrees of success. These initiatives range from providing nutrition, added human resources, and high-quality curricula. Curricula here refers to all materials and modes of instruction that support high quality teaching and learning. High-quality curricula are those that address and optimize national or state-mandated content standards and are developmentally appropriate, cognitively demanding, and culturally and linguistically accessible (Steiner et al., 2018). According to the Next Generation Science Standards (NGSS, 2013), a high-quality science curriculum is one that integrates STEM. STEM education emerged to develop teacher's knowledge for integrating STEM disciplines. However, various studies report on the challenges for conceptualizing and enacting STEM education, due in part to the various demands for discipline specific knowledge and skills. In fact, many teachers struggle with defining STEM education (Holmlund et al., 2018). However, targeted professional development with a combination of content knowledge and teacher feedback can help develop teacher knowledge and skills for teaching and integrating STEM topics (Aguirre-Muñoz et al., 2021; Madani, 2020; NSB, 2020). Next, we discuss elements in professional development crucial for supporting teachers working in impoverished schools.

Professional Development Professional development (PD) is offered to employed teachers to support ongoing professional growth. PD is provided by educators and school leaders at the school, district, state and national levels and is often required to gain recertification of teaching credentials (Georgia Professional Standards Commission, n.d.). PD that targets the development of pedagogical content knowledge (PCK) is essential because it increases teachers' confidence in teaching the content and implementing highly effective practices that best support student content learning (Kang et al., 2018). Along with increasing content knowledge by participating in PD, teachers can also learn new skills such as using new technologies and resources. Professional Development can also help increase teachers' positive attitudes towards integrating STEM curricula and their ability to collaborate with colleagues, which are two key aspects to ensuring continued and enduring implementation practices (De Meester et al., 2020; Thibaut et al., 2018).

Some PD provide teachers with additional resources to teach in novel ways. In ideal classroom situations when teachers use available resources effectively, such as laboratory equipment or digital tools, they maximize instructional value. However, for teachers working in impoverished schools, opportunities to participate in PD are often minimized for different reasons including geographic isolation or school-bound commitments that prevent them from participating. For example, teachers working in impoverished schools may not be funded for travel and lodging to attend PD in distant locations or may not be released from teaching because limited funding for teacher substitutes (Banilower et al., 2018). As such, structural funding inequalities prevent these teachers from professional growth and access to free instructional resources.

Need for Quality PD and Resources Lack of quality and access to instructional resources and PD prevents teachers from providing high-quality curricula (Owens and Georgia Department of Education, 2015). Often, teachers in low-SES schools use their own monetary funds and their own ingenuity, including household items or free-of-charge resources to provide students with authentic STEM learning experiences. Teachers' ingenuity can be confined within teacher professional agency, or "teachers' initiative and decision making to reach a certain end" (Bandura, 1986; Eteläpelto et al., 2013, as cited in Imants and Van der Wal 2020, p. 61). Thus, when nestled in a positive school ethos, teachers' PCK, effective use of resources, and teacher professional agency for maximizing learning are high priority instructional elements for supporting teachers and student learning (Maclellan, 2016). It is this kind of disposition that teachers working in impoverished schools rely on to enhance STEM instruction. Though a great asset, teachers' overreliance on ingenuity should not be the norm to teach science effectively. Rather, teachers working in schools with limited funding, above all, should be supported with quality PD and resources to provide quality instruction to their students. Thus, it is imperative that in addition to increasing PD and resources for teachers working in impoverished schools, policies, practices, and educational funding should also target the development of school leaders' critical consciousness to enact much needed social change regarding teacher training and resource availability (Dover et al., 2020). In this effort, the possibilities for a school ethos of supporting social justice education and teachers' professional agency for enacting high-quality curricula are maximized (Maclellan, 2016; Rodriguez, 1998, 2015).

6.2.3 Funding and Accountability Measures for Training STEM Teachers in Georgia

Tracking of educational funding for teacher professional growth is a complex endeavor because monies are gathered from different sources; that is, private and government agencies, and partitioned though elaborate funding formulas. For example, different government monies are appropriated to support high quality STEM education. Title II Part A federal funds appropriate monies to states to further develop teachers' PCK in math and science. In the state of Georgia, Regional Educational Service Agencies (RESAs) utilize Title II funds to conduct teacher PD. Also, Title II Part D federal funds allocate monies to improve technology use in schools. To supplement funding needed to support curriculum quality, school leaders can also appropriate other kinds of available funding from other sources. Lastly, additional public funding can also be gained by some educational systems that have "more experienced and more educated teachers" (Rubenstein & Sjoquist, 2003, p. 15), and through merit-based, performance pay bonuses for individual STEM teachers (Jones & Hartney, 2017). However, merit-based and performance-based funding accentuates persistent social inequities often experienced by teachers working in impoverished school systems. It is often the case that social capital is minimized in impoverished schools because they have historically been unable to attract and retain highly qualified teachers and often lack STEM-based materials and funding to carry out highly effective instruction. These conditions often deter highly qualified teachers from working in these schools (Clark, 2018).

In the past, STEM PD in Georgia was often conducted by RESAs through Math and Science Partnership programs (MSP). MSPs were funded through the No Child Left Behind Act-allocated funds for STEM education. In the advent of the Every Student Succeeds Act (ESSA) in 2015, funds for the MSPs were cut in 2018 and these monies were reallocated. Like public-school funding allocations, reallocated funding for PD in STEM education is difficult to identify due to complex funding formulas (Davis and Ruthotto 2019). In a recent and informal interview with a Southeast RESA director previously assisting with MSP teacher recruitment, Leah (pseudonym) mentioned not knowing where these current relocated funds exist.

However, RESAs continue to provide PD for teachers by offering physical and virtual workshops, and teachers can choose PD that is appropriate for their professional growth. In the teacher recertification process, which occurs every 5 years, Georgia teachers are expected to provide evidence of PD participation for professional growth. Established practices for determining which PDs teachers should complete are offered by supervising leaders; however, the onus for PD completion remains with the teacher. A teacher may choose to grow their expertise in any pedagogical or content areas, and not necessarily in STEM. Within the last decade, PD requirements for Georgia teacher recertification came to a halt. Between the years of 2011 and 2017, teachers were not required to evidence professional growth other than meeting PD expectations posed before 2011. Moreover, in the advent of COVID-19 pandemic restrictions, professional growth may have been redirected to develop needed skills for effectively carrying out virtual instruction. In essence, little to no accountability exists for STEM teachers to grow STEM competencies unless it is specifically suggested by leadership or teachers are motivated to do so.

6.2.3.1 Limited Accountability Measures for Professional Growth

Lack of accountability measures for STEM-focused professional development have hampered the kind of curricula teachers enact and low-SES, CLD students are often affected the most. While various agencies such as the National Science Foundation (NSF) and the US Department of Education provide STEM education funding opportunities through competitive grants, systemic underfunding of STEM teacher training particularly for teachers working in impoverished schools has been noted. The need to provide STEM-focused PD to teachers working in impoverished rural schools was important for two directors of a Southeast Georgia Math Science Partnership program (MSP). The authors share interview responses of the co-directors regarding this MSP. Both co-directors were faculty members at the university where the co-authors teach. Larry (pseudonym) is a previous science teacher and educator and director of the university's STEAM Center. Elena (pseudonym) is a seasoned math teacher, previous school principal and a now a retired math educator. The regional university sits in a small Southeastern city surrounded by produce and cotton farms. The university serves a diverse student population of mostly White and Black students and a small number of Latinx students. Across the state, the university is well known for its teacher education programs and is among the top education degree providers. The highly funded MSPs were carried out from 2004 until 2018, when MSP funding was officially terminated. The first author was also employed as a science instructor for the last 4 years of the MSP.

In an interview with MSP lead director Larry, he shared that he applied for MSP grants to provide much needed high-quality PD to local math and science teachers. This sentiment was also shared by Leah, RESA Math and Science PD director in her interview. Leah also stressed the need to provide MSP PD to rural teachers because they are often geographically isolated from one another, thus minimizing opportunities for networking and collaboration. Larry's efforts for targeted MSP PD were successful. The MSPs were well attended by math and science teachers. According to Larry, "When state funds were low to support the MSPs, local school districts appropriated additional funds to keep the program going." Larry attributes the success of the MSPs to highly engaging PD that incorporated effective use of technology, hands-on minds-on and inquiry-based activities. Larry shared that "Teachers learned math and science as students. They discovered it by themselves." He added, "Instructors' modeling of effective practices was the most important aspect of the PDs. Teachers often came to me to share what they had learned and applied in their teaching."

When Larry was asked about how participating teachers were held accountable for implementing the newly gained STEM knowledge, he explained that at first, there was no accountability for implementing what they learned in the PDs. However, over time, teachers began to be held accountable about implementing the strategies they learned by providing targeted feedback. When asked about accountability measures between PD they experienced and social justice agendas, Larry explained that in this regard, strengthening teachers' PCK was most important so that students experience success with highly trained teachers. But when asked about how teachers were held accountable for implementing high quality STEM curricula and tying these practices to student achievement, Larry explained that logistically, it was very difficult to hold teachers accountable. Larry shared that "There were too many teachers to track."

Codirector Elena corroborated Larry's understanding for the lack of accountability for STEM-based curricular implementation. In her interview about the MSPs she codirected, Elena first commented on her motivations for providing MSP professional development to local teachers:

> As I moved from single-system Teacher Quality professional development grants to the Math Science Partnership (MSP) grants, my colleagues and I realized how powerful a multisystem workshop for mathematics and science could be. Seeing the positive results of the

summer workshops combined with the within-year activities motivated us to continue serving math and science teachers in the local RESA area for many years.

When asked how teachers were held accountable for the implementation of the STEM curriculum, Elena explained that

> Accountability measures for effective PD are implemented via an evaluative process. However, evaluating the efficacy of grant-based PD is difficult. The expectation of application of strategies is high, for both participants and leaders, during the PD workshops itself. Along with individual teacher resistance to curricular implementation, challenges with within-school teacher collaboration makes it nearly impossible to maximize the intended effects of the PD and to hold teachers accountable for implementing curriculum.

Elena goes on to explain that the MSP attempted to maximize the number of participating teachers at every opportunity, particularly from individual schools in order to encourage curricular collaboration and implementation. However, due to large geographical separations between the schools and the university, and limited collaboration from teachers within the school, it was difficult to track collaboration and evaluation of teachers. According to Elena,

> Teachers in the PD came from twelve or more school systems, and not all teachers in given groups were participants. For example, if a high school had six biology teachers and all six attended the workshop, the potential for systemic [curricular] change is very high. If only two or three of the six attended, the potential for change is greatly reduced.

Elena provides an example of a strategy that evidenced the implementation of the newly gained STEM-based PCK and its approaches that were introduced during the MSPs. She shares that,

> Some effective evaluation procedures were designed for some within-year activities and implementation of science-bound discovery activities. The required documentation included photo documentation of activities and photos of learning outcomes. The grant investigators and the evaluator felt that these requirements did hold teacher-participants appropriately accountable.

Elena elaborates her response to assert that “We all know that a few activities do not produce a consistent change. To affect any school change, systemic change is needed.” When asked how teachers were held accountable for the implementation of socially just practices, Elena explained that,

> Socially just practices by teachers are potentially changed by PD activities and teaching, but it is probable that the most persistent influence on teachers’ socially just practices come from the [educational] system, and more specifically from the teachers within their teaching department and school. Our professional development activities focused on providing mathematics and science experiences for all level students, including special needs students. For all MSP workshops, we ensured that teachers of students with special needs were participants. My opinion is that those who provide PD should be intentional in including cultural diversity training and resources. Maybe more importantly, teachers should be taught how to provide strong instruction to disadvantaged students. Modeling positive experiences in professional development can be a powerful motivation.

Elena’s leadership for professional learning was heartfelt. Many teachers give credit to both Larry and Elena for the learning opportunities they experienced, and many teachers remain connected to the university as they seek additional PD opportunities. Larry and Elena’s assertions acknowledge that although the MSPs brought successful learning opportunities to our local teachers, the implementation of the strategies learned from the MSPs were superficially measured or not accounted for at all. Most importantly, teachers were not provided the opportunity to examine existing educational inequalities in STEM education and how to best meet the needs of low-SES and CLD students that they serve.

As a science instructor with expertise within the MSP for 4 years, the first author focused on teaching science that enriched the content standards, particularly with increasing teachers' experiences with wet labs. Participating teachers delved deeper into the science content standards but also learned topics that are often skimmed or omitted from traditional teacher-based science courses, due in part to time constraints. Examples of content enriching topics taught included the examination and purpose of scientific modeling, e.g., conceptual and physical models and the use of different scientific models to study natural phenomena; and the effective use of STEM-based apps and tools (Suriel, 2021). Teachers were also exposed to local community and natural resources so that they could utilize them in their instruction. In every workshop, teachers learned about strategies to support language development for English language learners. During one workshop, an entire day was devoted to soil science. Instructional activities on soil science were designed to draw on students' knowledge and familiarity with soils for growing crops in these areas.

The goals with using these resources were to acquaint teachers with opportunities for enriching the curriculum and to draw from students' funds of knowledge. However, more could have been done to increase teachers' awareness of socially just practices. Though teachers were very likely aware of their students' everyday experiences because they themselves are natives of this region, in these workshops, teachers did not get to examine how science curricula can make use of students' funds of knowledge and use that knowledge as a starting point of discussion. This pedagogical strategy was not specifically addressed in the workshops because the first author was instructed to only address science content given that another teacher-instructor would address pedagogical strategies. However, discussions on the program revealed that an emphasis on social justice education was never conveyed by the teacher-instructors nor the directors of the program. In essence, participating teachers gained a deeper understanding of specific science content and learned some inclusive strategies to engage CLD and low-SES rural students, but teachers did not learn about social justice education and had limited exposure on designing instruction to meet needs of the CLD students, ELLs in particular, and to draw on students' funds of knowledge.

6.2.4 Two Educators' Ongoing Efforts and Practices to Support STEM Education

In our work, and considering limited STEM-based PD opportunities, the authors became acutely aware of the manifest need to provide STEM-based professional development. We are two female science and math educators, one of Latinx immigrant ethnic background, and the other of White background, working at the university and with rural school teachers serving high numbers of CLD and low-SES students. Both authors have experience teaching in public schools, one high school and the other elementary, and are current teacher educators and field supervisors. In this section, we provide some examples of our successes with STEM teaching our university students. We then discuss our challenges with seeking funding for STEM PD for our local teachers.

6.2.4.1 The STEMITL Project: An Enriching Opportunity for Multiple Stakeholders

To better prepare preservice teachers to teach STEM, the Science, Technology, Engineering and Mathematics Integrated Teaching and Learning (STEMITL) project was implemented, pre-COVID-19, with undergraduate middle level education seniors. The STEMITL project was conceptualized and directed by this chapter's first author, was carried out at the university's STEAM Center, and was funded internally by the university with a small grant of $30,000. Multiple stakeholders participated in this project including 5 different faculty members, 30 preservice student-teachers, and 430 culturally diverse, low-SES rural middle school students and their cooperating science teachers.

The faculty of the middle grades program collaborated with our student-teachers to codesign an interdisciplinary STEM-based curriculum focused on water pollution. Each design team was charged with creating lessons that integrated STEM and enhanced content knowledge within each discipline. The curriculum was taught by the student-teachers three times a semester for one year. They taught middle school students and asked them to: (a) examine social issues related to water pollution, (b) collect and analyze pH data of water from a local river to determine potential causes of water pollution, and (c) argue for social reforms that impact the health of water sources. Students use of technology was also an integral part of the curriculum and assisted student-teachers with instructional delivery but also with developing middle schoolers skills with use of various apps (e.g., data tabulating and analysis, creating visually enhanced texts, and communicating with other students across the globe). The STEM curriculum did not incorporate the "E" in STEM for designing technology to better assess and monitor water pollutants. However, discussions on environmental chemistry regarding industrial and farming chemicals that pollute local bodies of water were carried out. Such discussions were pertinent to students' lives in this context given the agrarian culture in this region. The faculty also thought it important to discuss ecofriendly behaviors and practices for protecting local water resources.

At the completion of the project, the student-teachers completed a survey about their experiences with the project. The 19-item survey consisted of 16 quantitative items and 3 qualitative items. Quantitative items' responses ranged from 1 to 5 on a Likert scale, with the highest score indicating the most positive response. Prominent findings from the survey indicated an increase in student-teachers' passion for teaching. For example, the highest ratings were for survey item 13 *This experience fueled my passion for teaching* ($N = 30$, $M = 4.57$, $SD = 0.72$) with 93% of students selecting a 4 or 5 as choice responses. Likewise, survey item 16 *This experience was a good way for me to improve my teaching techniques,* was also a high scoring item ($N = 30$, $M = 4.53$, $SD = 0.63$) with 93% of students selecting a 4 or 5 as choice responses. Another high-scoring survey item indicated that compared to White student teachers, Black student-teachers had more positive attitudes about their ability to apply integrated STEM curricula to different grade levels as a result of participating in this project. Descriptive statistics for this item show Black student-teachers' ($n = 9$) response Mean was 4.78 and Standard Deviation of 0.44 with 100% of students selecting a 4 or 5 as choice responses. Descriptive statistics for this item show White student-teachers' ($n = 20$) response Mean was 4.3 and Standard Deviation of 0.73 with 90% of students selecting a 4 or 5 as choice responses. One student did not identify their racial background, thus for this item their response was not evaluated.

Data gathered from qualitative survey items also indicated student-teachers' increased appreciation for experiencing STEMITL and for learning interdisciplinary strategies to teach it. For example, one student-teacher shared that "The most valuable thing…was getting to see the interdisciplinary curriculum… that is rare in the education system we have right now." Another student shared that "Until this experience, I too would have been guilty of not seeing that each subject can be connected…intertwined together as opposed to having each subject develop their own island of course content." Also, fieldnotes indicated that all participants, including faculty, were actively engaged in the conceptual understanding of water pollution as a socio-scientific issue. Interestingly, cooperating science teachers also learned from this experience and modeled parts or the entire project in their schools with their students. For more information on the STEMITL project, see Suriel et al., 2018.

The STEMITL curriculum benefitted local and rural low-SES and CLD students as they participated in a STEM-based enrichment opportunity. Their enthusiasm and excitement for learning showed in their facial expressions and demeanor throughout each STEMITL day. It was motivating to us, the faculty and the student-teachers, to offer a socially and academically just learning opportunity to our local students. Though funding for this project was limited, multiple stakeholders benefitted from this PD that was modeled with real students. With additional funding, this project could have gone further with incorporating more engineering practices, such as examining conceptual models or designing technology for monitoring water pollution or designing instruction that better defines social justice perspectives and approaches. Such approaches would have better modeled the integration of STEM and social justice education. Moreover, additional funding could help extend these experiences to future students, including elementary education students and teacher leaders. In doing so, the student-teacher population sample could be augmented providing us with opportunities for more rigorous data analysis (e.g., ANOVA) to detect any statistically significant differences relevant to this study.

6.2.4.2 Planning and Teaching Integrated STEM Lessons in the Mathematics Methods Courses

Elementary-level student teachers are often trained to integrate curricula. One advantage for elementary teachers is that they plan and teach lessons in multiple subjects such as science and mathematics, which helps them gain a better understanding of how these subjects relate (Bakirci & Karisan, 2018). However, effectively integrating STEM curricula may not be a required skill in their teacher education courses nor in PD (Banilower et al., 2018). To better assist elementary level teachers with integrating STEM curricula, the second author designs course activities that immerse students in the planning and teaching of integrated STEM. STEM integration in her course assignments include instruction that is student-directed and uses technology applications of mathematics and engineering practices.

One example of how students demonstrated integrated mathematics and student-directed technology use in a course assignment was when a student-teacher planned for her students to design animal pens for a farmer. For this activity, students were expected to use (a) science knowledge relating to animal needs for the size and shape of pens (relating to prior science lesson where they went on a free virtual field trip to a farm), (b) use free web-based virtual manipulatives to design and engineer their pens, and (c) mathematics to compare area and perimeter of the pens. In her reflection, the pre-service teacher noted that the students really enjoyed the activity because it was "more real to them than just solving problems on a worksheet." Many students noted in their reflections that they plan to teach more integrated STEM lessons in the future.

In another example of a graduate level course assignment, students were asked to showcase STEM integrated activities. One teacher had elementary students design "Leprechaun traps." For this activity, students were expected to use (a) virtual manipulatives to design their traps, (b) mathematics for measuring the dimensions of their geometric designs, (c) physics knowledge with designing moving parts, and (d) use engineering knowledge to build their traps using everyday objects from around their house (bottles, rubber bands, Legos, cardboard, etc.). Video submissions and teacher reflections for this assignment showed that not only did the students and teachers enjoy the integrated activity, but the young learners were engaged in higher-order thinking that supported a deeper understanding of the content. Teachers indicated in reflections that they intended to continue integrating STEM subjects. This course assignment shows that when provided with learning opportunities to integrate STEM, teachers can design and implement low budget but engaging STEM curriculum to support student learning.

These examples show that as teachers have opportunities to plan and implement STEM integrated lessons, even with limited funding, they can see the value of the lessons for student engagement and learning. One limitation of using university courses to improve STEM teacher education is that the population is limited to those teachers who are willing to pay tuition at the university. In order to create sustainable change, these same opportunities for STEM PD need to be expanded to local teachers who may not be able to afford university tuition.

6.2.5 Ongoing Initiative for STEM Education Professional Development with Inservice Teachers

The termination of funding for MSPs and current state budget cuts for PD motivated us to seek opportunities to provide continued STEM PD to local teachers. As such, we sought funding sources to sponsor this work. Drawing on what we learned from our colleagues who previously directed the MSPs, our intended goals for the year-long intermittent PD were to provide PCK enrichment regarding science, mathematics and technology, inclusive of computational digital literacy and social justice education. We targeted one group of same grade teachers working in the same school that served low-SES and CLD students. For the summer PD, we sought the participation from their school leaders. We also aimed to purchase digital devices for teachers to keep and use for instructional purposes, as suggested by Rodriguez and Morrison (2019). In the years that follow, we planned for the first-year teachers to train other teachers in their own schools. To gather evidence of teacher professional agency for enacting newly gained socially just STEM instructional approaches, we planned research using both qualitative and quantitative methods. In our design, we planned for connecting teacher effective instruction to student achievement and student motivation for learning STEM.

As the result of this agreement with the school principal for STEM targeted PD, we sought another source of funding to conduct the PD. We identified a grant funding opportunity offered through a renowned educational association targeting educational inequalities – made prominent by the COVID-19 pandemic. Again, we did not secure any funding for this PD when our grant proposal was declined. At this point amid the COVID-19 pandemic, all internal university-bound funding grants were suspended, further limiting funding opportunities. Although we continue to seek support from various funding sources to provide incentives for teachers to participate in the STEM-based PD, we may not be able to secure timely funding, and will be providing in-kind PD to support teachers' needs once pandemic restrictions ease.

6.3 Conclusion and Recommendations

Persistent educational inequities continue to plague the development of scientific literacy for low-SES and CLD learners. While many calls have been placed to address structural inequalities, these efforts have not affected the needed social change to transform STEM curricula that meets the needs of the low-SES and CLD students. Inadequate school funding makes evident the lack of commitment to these calls. In fact, public funding has decreased since the Great Recession of 2008 particularly for schools serving low-SES children (Black, 2019). Limited funding for STEM school programs and STEM-focused professional development has hampered ongoing efforts to effectively address and support teachers' knowledge gap on STEM and social justice education. In the state of Georgia, a lack of accountability measures for professional growth deteriorates the quality of curriculum students experience. This is a disheartening issue and unjust practice that places the most vulnerable learners at a competitive disadvantage for acquiring top-notch STEM education that can potentially transform their lives and future careers.

We presented the case of a regional Georgia state-funded Math and Science Partnership professional development that ran consecutively for 14 years. The goal of the MSP was to provide much needed STEM-focused PD, mainly science and mathematics, to rural and local science and science teachers near a small Southeastern city university nestled amidst produce and cotton farms. The well-funded MSPs were successful with their goals; however, demonstrably inconsequential as they failed to substantially evidence the enactment of the STEM approaches introduced. Moreover, the MSPs marginally focused on issues of socially just instruction. Part of the challenges discussed by one of the codirectors of the MSPs is keeping a balance in the enrollment of participants. To effect school change for the enactment of newly gained PCK resulting from the MSPs, she suggested targeting teachers from the same schools to maximize collaboration. However, she did not suggest how to best evaluate the efficacy of the PD regarding curricular implementation of learned approaches. Lastly, she suggested that PD administrators be intentional with training teachers about cultural diversity and modeling how to best teach it. Rodriguez and Morrison (2019) argue that the efficacy of any efforts for transformative change can be best addressed through narratives of engagement. That is, this approach seeks to balance a discussion of the "challenges and successes encountered with teaching and learning in culturally diverse contexts and of the responsive (and responsible) role of the researchers in bringing about social change" (p. 278).

The coauthors of this chapter also showed how they sought to address and increase STEM PCK in student teachers. The first author showcased a low-budget STEM project that benefitted multiple stakeholders. This project's research findings illustrate that teachers' ingenuity for effective instruction can be supported through concerted efforts from socially just and critical friends. However, financial support for the many educators (faculty, staff, student teachers, and cooperating science teachers) who carried this project over many days was minimal or altogether missing. It is this kind of work that needs financial compensation to sustain more equitable practices and experiences for CLD student teachers and their future CLD students.

Lastly, we shared our experiences seeking grant funding to finance STEM-focused professional development. We considered lessons learned from our colleagues to design effective PD and adhered to the recommendations made by Rodriguez and Morrison (2019) for researcher practices with connecting PD efficacy to sociotransformative change. As such, our grant proposals specified research methodology to include both quantitative measures to expediently analyze data connecting teacher implementation of PD practices to student achievement, and qualitative measures to document the roles of teachers and researchers in bringing positive social change. Unfortunately, after seeking grant funding on two different occasions, our grant proposals were declined. However, we persist in our efforts to provide much needed STEM PD to our local teachers, especially because of recent state budget cuts for PD and lack of accountability for professional growth.

Collectively, our stories highlight the need for funding STEM-based, socially just PD and increased PD accountability measures for professional growth in teachers. We brought awareness to different challenges posed to public education and research in low-SES and rural school contexts. We conclude by offering one more consideration aimed at public and private grant funders. Large geographical distances between schools and students and teachers are not often accounted for when considering adequate funding. Teachers and students may not only be socially disconnected but also physically isolated from meaningful diverse cultural interchange. While social media may provide a forum for cultural interactions, intermittent digital connectivity presents an additional barrier. Thus, it is important that funding sources consider these additional challenges if we aim to enact more socially just practices for rural, low-SES and CLD students.

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